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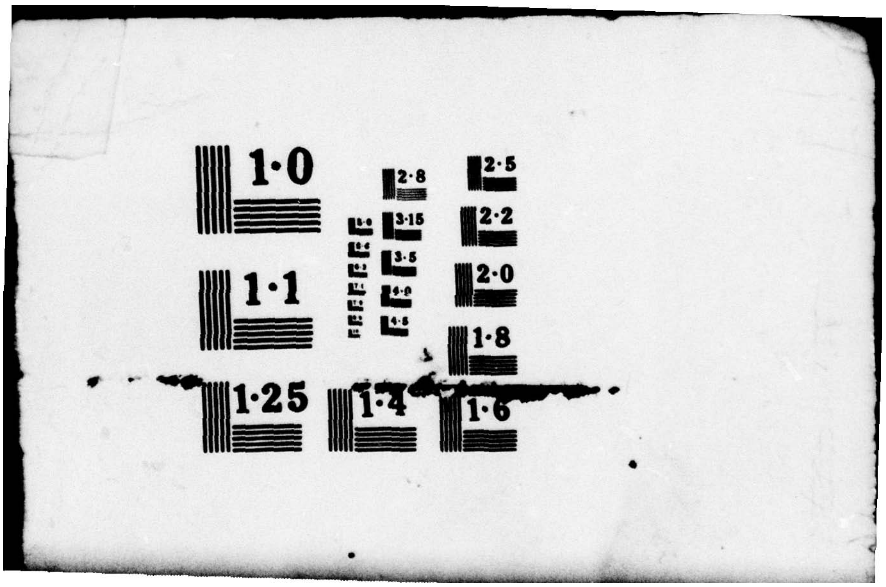
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INDIVIDUAL FIRE FIGHTER COMMUNICATIONS

NORMAN D. KNOWLES

ENGINEERING RESEARCH DIVISION

FIRE PROTECTION BRANCH

MARCH 1979

FINAL REPORT

OCTOBER 1976-JULY 1978

APPROVED FOR PUBLIC RELEASE;
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UNITED STATES AIR FORCE
ENGINEERING AND SERVICES

AFESC

ENGINEERING AND SERVICES LABORATORY
AIR FORCE ENGINEERING AND SERVICES CENTER
TYNDALL AIR FORCE BASE, FLORIDA 32403

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The Engineering and Services Laboratory (ESL) conducted an evaluation to fulfill an operational requirement for an individual, two-way communication system for fire fighters. Contracts were initiated in April 1977 to obtain the basic radios and as a result of this procurement action, integrated systems were bought and tested. The accessories included a new type hood, helmet and breathing system. This new hardware was tested because it appeared to offer the greatest potential for satisfying the stated needs of the operational fire → next page

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protection units within the United States Air Force.

The primary objective of this equipment evaluation was to provide a procurement description (specification) of the items of equipment needed to satisfy the operational requirement so that authorization documentation could be developed or revised.

The Operational Test and Evaluation Program was initiated with the dissemination of the Test Plan in April 1977 and was concluded June 1978.

The Operational Test and Evaluation (OT&E) program was conducted at Tyndall AFB, FL, Barksdale AFB LA, and Nellis AFB NV. The dedication and cooperation of the major air commands, base commanders and their staffs and base fire department personnel at these bases was vital to the orderly conduct of the OT&E and was greatly appreciated.

PREFACE

This report was prepared by Detachment 1, AFESC (CEEDO) CNS, Tyndall Air Force Base, Florida 32403, under Job Order Number 414N3003. The information contained herein describes work performed in pursuance of individual fire fighters communications by the Civil and Environmental Engineering Development Office.

Effective 1 March 1979 CEEDO was inactivated and became the Engineering and Services Laboratory (ESL), a Directorate of the Air Force Engineering and Services Center located on Tyndall AFB Florida 32403.

This report summarizes work done between October 1976 and July 1978. Mr Norman D. Knowles and Mr Lawrence W. Redman were the project officers. Final technical report preparation was accomplished by Mr Joseph L. Walker.

This Technical Report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This Technical Report has been reviewed and is approved for publication.

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SECTION I
INTRODUCTION

It has been generally accepted by experienced firefighters that supervision and control of individual firefighters are impaired at the scene of a building or aircraft fire through the loss of direct communications. Effective communications cease from the initial response until termination of the emergency. Firefighters are often required to perform without the benefit of supervision in hostile environments and remote locations isolated from observation by their supervisory personnel.

Consequently, during June 1970 an Air Force Required Operational Capability (ROC) was confirmed for an individual two-way communications system for firefighters. The communications system was envisioned to complement but not to replace the fire crash/radio. In October 1972, the DOD Aircraft Ground Fire Suppression and Rescue Office (ACFSRO) received a Program Management Directive which gave formal approval for the procurement of a limited quantity of commercially available portable radios. In June 1973, 38 basic radios and an equal number of sets of accessories were purchased. The OT&E was initiated on 27 February 1975 and continued through July 1975. The recommendations were that a change be initiated in the number of radios made available to the firefighters. Secondly, that resources of Air Training Command and Human Resources Laboratory be tasked to develop and assess techniques for assuring proficiency in the use of radio communications, and finally that a development program be authorized to exploit the benefits of a full-duplex system with possible application to all firefighters.

In October 1976 a test plan was prepared to study a full-duplex system for firefighters (both aircraft crash and structural). The ultimate objective of this equipment evaluation was to provide a procurement description (specification) of the items of equipment needed to satisfy the operational requirement so that each service's authorization documentation could be so revised.

The results of that test are contained within this technical report.

SECTION II
TEST PROGRAM TASKS

GENERAL

The Firefighter Communications System is intended to provide the capability for direct voice communications between fire fighting personnel at the operating location and was used in accordance with the Operational Concept (Appendix A), prepared specifically for the Firefighter Communications System. Therefore, in this regard, the system is a complement to and not a replacement for the fire/crash radio net located in the fire station and mobile fire vehicles.

During a previous evaluation of SAC ROC 12-70 and the operational concept, a full test program was conducted to assess the power, sensitivity , frequency, and modulation capabilities required to meet the stated requirements. Several configurations of radio equipment for the intended application were obtained for this test. As a result of this effort, a UHF/FM type radio was determined to be the most suitable. AM type radios were found to be unacceptable, and VHF/FM radios were marginally suitable.

It was determined that 12 months of testing would be required to fulfill the IOT&E with testing to begin on or about June 1977.

TASK ORGANIZATIONS

The following organizations were tasked to assist in the overall IOT&E Program:

1. HQ AFESC/RDCF, Tyndall AFB FL 32403 - Project Manager.

2. 1842 EEG/EEI, Scott AFB IL 62225 - Communications Electronics Engineering Consultant.

3. 6570 AMRL, Wright-Patterson AFB OH 45433 - Human Factors Engineering Consultants.

4. AFHRL/TT, Lowry AFB CO 80230 - Evaluation and Training Consultant.

5. 4756 ABG/DEMF, Tyndall AFB FL 32403 - Operational Testing.

6. 57 CSG/DEF, Nellis AFB NV 89191 - Operational Testing.

7. 2 Bomb Wing/DEF, Barksdale AFB LA 71110 - Operational Testing.

TEST OBJECTIVES

1. Main Objectives:

a. The objective of this test was to evaluate a command and control communications system for use during fire fighting operations involving aircraft and structural fires.

b. To determine if individual firefighter communications are compatible with breathing apparatus and head protection for both crash and structural fire fighting operations.

2. Specific Sub-Objectives:

a. To determine the effectiveness of additional communications in fire fighting operations.

b. To determine operational capability of several communications configurations.

c. To determine the basis of issue for communications equipment.

d. To gather preliminary information concerning reliability, maintainability, life cycle cost, logistics support and systems safety.

e. To identify procedural changes and attendant training requirements.

DESCRIPTION OF EQUIPMENT

Portable HT220 Radio. A commercial *HT220 Handi-Talkie® radio* was the basic element of this system. The Handi-Talkie® FM radio was a 4-watt portable two-way communications unit. It was powered with rechargeable nickel-cadmium batteries. It can be used singularly as a hand-held push-to-talk walkie-talkie type of radio. Controls on this unit included a two-channel frequency selector switch, squelch, push-to-talk (PTT) switch, and on-off-volume switch. An auxiliary antenna could be connected to the basic radio by plugging an antenna lead into the antenna jack located next to the radio's antenna.

Cairns, Philadelphia, Polycarbonate type Helmet (Structural Mode). The helmet was made of pure Lexan® polycarbonate. It was designed and fabricated to provide limited protection against injuries to the head when worn by firefighters during their normal fire fighting activities. It met or exceeded the performance requirements established by A.N.S.I. Z89.1-1969. The radio system installed in this helmet was a UHF/FM (16F3) two-way voice communications system, crystal tuned to a transmit and receive frequency of 413.275 MHz. The radio was integrated into the helmet shell and provided effective and reliable voice communications over typical line-of-sight ranges of at least 2,000 feet.

Activation of the transmit mode was accomplished by either of two selectable modes: mode 1, push-to-talk; mode 2, VOX while retaining

push-to-talk override. The control transmit mode selector on-off and squelch was provided on the right side of the helmet top rear to permit activation by a mitted hand stroke. The squelch tail was held to an absolute minimum. The transmit keying circuit contained necessary interlock circuitry as to render keying of the transmitter by push-to-talk or VOX impossible as long as there was a received carrier being demodulated by the associated receiver. The antenna was a flexible (rubber) type located on the rear of the helmet. Care was taken to assure that the antenna presented a negligible projection that could be caught or hooked onto by passing lines, wires, ropes or other obstructions. The speaker was mounted on the helmet in such a manner as to provide clear and intelligible audio reception by the wearers at all times.

The microphone was the noise cancelling type and was mounted in such a manner as to present a minimum protrusion from the helmet configuration. The entire helmeted system was powered by a rechargeable lightweight battery with a minimum continuous received signal or transmit keyed life of 30 minutes. The supplier configured the microphone type and placement to afford a direct interface into a breathing apparatus with an absolute minimum connector changeover requirement. It was highly desirable that no microphone or connection changes be required when going from a no-mask to a masked operation.

The supplier of the communications system included a battery charger capable of charging a minimum of four units at a time for each three helmets procured. The battery charger was capable of being powered by two sources, these being 115 volts AC, 50 60 Hertz, and 24 volts DC. The helmeted system was capable of receiving battery charging current without removing the battery from the helmet or from the transceiver itself. The charger also had provisions for recharging extra spare batteries removed from the system.

The entire communications system, including microphone, transducers (speakers), batteries, and circuitry did not exceed 8 ounces.

Fire Suppression and Rescue Helmet (Crash Mode). An advanced design fire suppression and rescue helmet system had been manufactured by the Life Support Systems Division of American Safety Inc for test and evaluation by the Naval Air Systems Command.

The American Safety fire suppression and rescue helmet system is for use by firefighters during entry and rescue operations involving direct exposure to flames in an irrespirable atmosphere. The system provided a supply of cool breathing air, protection for the head from flames, and a radio communication system. Prototype models have been tested by the Naval Medical Research Institute in Bethesda, Maryland. Demonstrations have been made to the Los Angeles Fire Department crash crews at the International Airport, Navy crash crews at the Miramar Naval Air Station and at the North Island Naval Air Station in San Diego, and to Naval Air Station personnel from around the nation at P4-A demonstrations at China Lake, California.

The helmet was made of fiberglass with an outer layer of aluminum. Protective covers of the same composite structure are also placed over the radio and breathing air components. An adjustable head support band for comfortable fit and foam pads for impact protection were provided on the inside of the helmet shell. A neck seal and an aluminized fabric cape were attached to the bottom of the helmet to protect the neck and to contain the cool breathing air around the head.

The helmet visor was made of a composite of Kapton® and Lexan®. The Kapton® provided the high temperature strength and protection against heat radiation. The Lexan® polycarbonate provided stiffness and mechanical attachment to the shell. An air valve was incorporated in the visor actuation knobs. Whenever the visor was up, the air supply was shut off; whenever the visor was down, the air supply was automatically turned on.

The radio, a UHF/FM two-way voice communication system crystal tuned to 413.275 MHz (transmit and receive), was integrated into the helmet shell, providing effective voice communication over typical line-of-sight ranges. Activation of transmit condition was accomplished by either of two selectable modes: mode 1, push-to-talk; mode 2, VOX. The controls and on-off-squelch knob were provided on the right side of the helmet. The push-to-talk button was located to permit activation by a mitted hand stroke. The antenna was integral with the helmet. The microphone and speaker were placed in the front of the helmet below the visor to provide clear and intelligible audio reception. The air supply was self-contained in flat-pack reservoir which was carried on the belt, chest, or back. All flat-packs were 2 inches thick and were encapsulated in a tough elastomer to seal out moisture and protect against rough usage. The flat-packs were available in durations from 3 to 15 minutes; the chest and back packs are available in durations up to 60 minutes. The flat-packs included push-button start valves, gauges and fill valves. The reservoirs were re-chargeable, using Navy shipboard charge stations or commercial booster charging stations.

The helmet-mounted air supply components included the visor-knob on-off valve, a swivel connector for the air hose from the flat-pack reservoir, a positive-pressure demand regulator and a compensated exhalation valve. The breathing system maintained a positive pressure inside the helmet to prevent in-leakage. Whenever the firefighter inhaled, the demand regulator would open to provide the breathing air required by the wearer's lung capacity and breathing rate. Whenever the firefighter exhaled, the demand regulator would shut off to conserve the supply of breathing air in the reservoir. The breathing air was cool, about 50°F, and helped to prevent visor fogging.

In operation, the system was donned by first strapping on the belt, chest, or back pack. The helmet was placed on the head and the quick-disconnect fitting on the air hose was plugged into the helmet swivel fitting. The start button on the flat-pack was then pushed and the visor turned to the down position. The firefighter was then breathing cool air from the flat-pack. Whenever the visor was lifted, the wearer breathed outside air and conserved the air in the reservoir. A new flat-pack could be donned at any time and plugged into the helmet in less than 10 seconds.

The radio was switched on by turning the on-off knob on the side of the helmet. The same knob was tuned as a squelch control. The volume control was preset and did not normally require adjustment. To transmit, the fire fighter pressed and held the push-to-talk button and then spoke in a normal voice or spoke into the microphone in the VOX position.

Portable Booster Charge Station. A small, lightweight charge station has been developed by the High Pressure Products Division of American Safety Equipment Corporation. It is a booster station which will increase the pressure of breathing air from bottles or compressors to 5000 psig. The station weighs 45 pounds, is 10 inches wide, 11 inches high and 18 inches long, and is intended for bench or table top use.

The station is used to pressurize the American Safety line of self-contained breathing equipment. In operation, it is usually connected to the outlet of any of the compressors commonly used by fire stations or SCUBA dive shops. In laboratory use, it may be connected to bottles of compressed breathing air. It will operate with inlet pressures between 700 and 3000 psig.

The characteristics of the portable booster charge station are as follows:

1. Air Input: Must be breathing air, Type I per Compressed Gas Association Commodity Specification G-71, Grade B or higher quality, at pressures between 700 and 3000 psig.

2. Electrical Input: 110 AC 15 amp maximum.

3. Charging Pressure: 5000 psig.

4. Overall Dimensions: 10 x 11 x 18 inches.

5. Weight: 45 pounds.

6. Charging Time: The nominal time at an inlet pressure of 1500 psig is 30 seconds per square cubic foot (SCF). At 2000 psig inlet pressure, the time is 12 seconds per SCF.

The pump is a single-stage, oil-free, reciprocating piston type. It is driven by a 1/2-horsepower motor. The breathing air input to the station is filtered and enters directly into the pump. The outlet of the pump pressurizes a gauge, a pressure relief device, and a pressure switch which automatically shuts off the motor when the charge pressure is reached.

Safety provisions in the Booster Charge Station are the following:

1. All pneumatic components are designed for 15,000 psig and are proof tested to 10,000 psig.

2. The pressure switch automatically shuts the pump off when the operating pressure is reached.

3. The pressure relief device is set to release at a 50 percent over pressure (7500 psig) in case of failure of the pressure switch. A fuse is also provided to prevent stalling and overheating of the motor.

To prepare the station for use, the following steps should be performed:

1. Connect the inlet port to a compressor or a bottle of compressed breathing air.

2. Connect the electrical plug to a 3-wire 110 volt AC outlet.

3. Check that the inlet pressure is between 700 and 3000 psig.

4. The station is now ready to use.

The general charging procedures are as follows:

Step 1. <u>CONNECT UNIT TO STATION</u>

The outlet port of the charge station is in the rear. Commonly a flex hose (rated to 10,000 psig or greater) is attached to this outlet port to make connection to the breathing equipment easier. The unit to be charged should be placed in a tank or enclosure as a safety measure.

Step 2: <u>TURN VALVE TO CHARGE</u>

This will permit the compressed breathing air to enter the station and the unit to be charged. The gauge pressure should read between 700 and 3000 psig before taking Step 3.

Step 3: <u>PUSH START BUTTON</u>

This starts the pump. The pressure shown on the gauge will increase at a rate dependent on the inlet pressure and capacity of the unit being charged.

Step 4: <u>PUMP STOPS AUTOMATICALLY</u>

At a pressure adjusted to be 10 percent above the operating pressure of 5000 psig, the pressure switch will turn off the pump. The slightly higher pressure is adjustable so that as the breathing equipment cools down to room temperature, a full charge of 5000 psig results.

Step 5: <u>TURN VALVE TO VENT</u>

This closes the line to the source of compressed breathing gas and bleeds the rest of the charge station to atmospheric pressure.

The breathing equipment being charged does not vent because of a check valve in the fill fitting.

Step 6: <u>REMOVE CHARGED UNIT</u>

Since there is no pressure in the outlet of the charge station, the unit may be disconnected easily and another unit connected for the next charge cycle.

There are a number of precautions which should be taken in using the charge station:

1. The unit being charged should be placed in an enclosure for safety.

2. Use only acceptable breathing air.

3. Never use hydrocarbon lubricants which may contaminate the breathing air.

4. If the source of breathing air is at a pressure below 700 psig, the motor may overheat and blow the fuse.

5. If the source of breathing air is at a pressure above 3000 psig, the motor may stall when the start button is pushed and blow the fuse.

6. The supply pressure valve (compressor or bottle) should be turned off when the charge station is not in use to prevent pressure loss.

7. If the ambient temperature at the charge station is high (above $90^{o}F$) in prolonged use at inlet pressures above 2000 psig, the motor may overheat and blow a fuse. It is recommended that the supply pressure be throttled to less than 2000 psig under these circumstances.

The charge station is designed to be maintenance free. The filter, valve, gauge, pump, and motor require no routine maintenance. If the fuse is blown it may be replaced by another 12 or 15 amp fuse. If the pressure relief device should actuate due to overpressure, a new safety disc must be placed in the device.

RESPONSIBILITIES

HQ AFESC/RDCF was responsible for the operational test program and functioned as the overall work unit manager. Representatives of HQ AFESC/RDCF were responsible for conduct of the test, data acquisition, evaluation of simulated operations, and preparation and coordination of the final test report.

The 6570 AMRL provided human factors engineering consultation for design, test, and evaluation of the operator/equipment interfaces of the firefighter communications equipment. Additionally, they coordinated with

AFHRL/TT to provide appropriate test methodology and data gathering requirements for human factors evaluation of the individual firefighter communications system and prepared those portions of the test report relating to human factors engineering or operator interface.

AFHRL/TT assisted HQ AFESC/RDCF in the development of questionnaires and scenarios; reviewed test procedures and methodology for completeness and accuracy; observed the operational exercises, provided statistical analysis and interpretation of questionnaires and time data for inclusion in the final report. They made recommendations about attendant training which would result from operational implementation of additional communications equipment.

The 1842 EEG provided engineering assistance to HQ AFESC/RDCF relative to the operational and technical evaluation of the communications equipment procured and tested. This assistance included on-site consultation during the performance of tests at Tyndall, Nellis, and Barksdale AF bases.

Participating fire departments conducted all exercises, structural and crash. They provided the expertise in the actual use of communications equipment, and submitted data on each use questionnaire to the appropriate agencies.

SECTION III
OPERATIONAL TEST AND EVALUATION (OT&E)

GENERAL

Air Defense Command (ADCOM), Strategic Air Command (SAC), and the Tactical Air Command (TAC) were designated by Program Management as the operational commands responsible for testing the equipment. Representatives from the Fire Protection Division at each major command headquarters selected a Fire Department at one of their respective installations to receive and test the Communications Hardware. The bases selected were Tyndall AFB FL (ADCOM), Barksdale AFB LA (SAC), and Nellis AFB NV (TAC).

Each base involved in the OT&E was assigned Radio Frequency 413.275 MHz to be used for the duration of the test program. The firefighters communications OT&E test plate was disseminated and a 6-month operational test and evaluation program was initiated in April 1978.

Before beginning evaluation exercises, representatives from RDCF, 184ZEEG and the contracting firm (American Safety Co.) visited each installation to indoctrinate fire department personnel. This indoctrination included test program objectives, test data collection and case and operation of the radio equipment and accessories.

The test program was conducted in three phases:

1. Tyndall AFB FL: The first phase was conducted by the 4756 AFB/DEF and was geared for validation of the operational concept and initiation of procedures and equipment. Simulated exercises were conducted in accordance with scenarios listed in appendices B and C.

2. The second and third phases were conducted at Barksdale AFB LA and Nellis AFB NV respectively, using similar procedures as outlined for the Phase I testing.

3. Representatives from HQ AFESC/RDCF, HQ AFESC/DEF, 6570 AMRL/HE, 1842 EEG, and AFHRL/TT were available during test, as required, at the test site locations.

SECTION IV
EVALUATION OF SYSTEM PERFORMANCE

This section is concerned primarily with evaluating system performance of the new communications equipment, under relatively realistic situations, where the equipment and users are considered a man-machine system. Secondarily, a brief assessment is made regarding the attitudes of firefighter personnel toward perceived usefulness of the new equipment and toward its introduction into the inventory.

The major question under study was that of proving (or disproving) the concept of individual firefighter communications.

Testing the individual communications concept implied answering two questions: (1) does the new system work? and (2) do firefighters like it? Thus, the two dimensions selected for evaluation in this study concerned effectiveness and acceptance.

RATIONALE

1. <u>Approach</u>. Evaluations are normally conducted in either of two basic ways--comparative or noncomparative. In the comparative approach, one method (system, device, etc) is directly compared with another method on some criterion or group of criteria. For example, two vehicles could be evaluated by comparing the top speed attained by each. In contrast, the noncomparative approach merely measures the item under evaluation against some (usually) prespecified level of performance on the criterion. Thus, a vehicle could be evaluated on whether it reached a top speed in excess of 100 mph.

Since it was difficult to specify in advance the desired levels of performance for firefighters using new communications equipment, it was judged more reasonable to adopt a comparative approach and measure the old and new systems with respect to their effectiveness. On the other hand, to determine user acceptability of the new equipment, a noncomparative approach was employed (i.e., a questionnaire survey designed to elicit firefighters' reactions to the new equipment only).

2. <u>Strategy</u>. The field experiment was the evaluation strategy used in this study. However, as the study progressed and we learned more about the field situation, our original plan for a purely experimental strategy required modification. By the time the last series of exercises was conducted, we had settled on a more observational approach which retained some of the features of a true experiment, but was not amenable to standard statistical analysis.

3. <u>Constraints and Limitations</u>. Practices, limitations in time, money, and manpower which were available for the evaluation made necessary some compromises to an absolutely definitive evaluation. These limitations should be kept in mind in interpreting the results, as well as noting some constraints which also may limit the conclusions. The most important constraint is probably a certain lack of realism in the test

exercises. Since safety was an important consideration, no environmental hazards (heat, smoke, etc) could be present in the experiment. In contrast to what is experienced in real-life, dangerous situations, little anxiety was present. With these exceptions, the problem situations were chosen by experienced firefighters to conform to realistic situations as much as possible. Next, since no actual fires could be set, we were forced to concentrate on only one aspect of the total firefighter job; namely, the rescue situation. Only the rescue team wore the individual transmitter/receivers; only they and the Deputy Chief had access to the rescue frequency. A third constraint pertains to the limited sample of fire stations. Only three of more than 250 which could have been sampled were actually studied. Finally, inherent in all field experiments is the lack of control of important factors such as subject motivation, organizational morale, variability in the way the problems were presented, and the experience and ability of the rescue teams.

METHOD

1. Effectiveness Measures. As stated previously, the focus of the experiment was on the rescue situation. Measures of effectiveness included: rescue time, number of communication attempts, and percentage of successful communications. It was felt that if the new communications equipment were better, a more efficient rescue would take place, (i.e., reduced rescue time). Rescue time was defined uniformly in all the exercises as time elapsed from first entry into the aircraft or structure to completion of the secondary search. Number of communications was included to determine to what extent the new equipment was actually being utilized. Percentage of successful communications would reflect in an objective manner the presence of any intelligibility problems with either the new or the old equipment.

2. Control of factors affecting effectiveness measures. Other than the type system employed--old or new--there were many factors which could have affected rescue time and communication frequency. These included: (1) general type of rescue situation--large frame aircraft, small frame aircraft, or structure: (2) crew factors such as experience, strength, endurance, team work, knowledge of correct procedures, voice clarity, and emotional control; (3) specific problem situation--problems could vary in complexity from situations with only minor difficulty to intricate situations requiring coordination of effort; (4) time of day--daylight or darkness; (5) environmental variation--temperature, humidity, wind, extraneous noises around the flightline, etc. We controlled for general differences in problems (large frame aircraft, small frame aircraft, structures) by looking at these three major types one at a time, in effect making three separate studies. Some of the other variables were controlled through counterbalancing. Thus, an equal number of day and night exercises were assigned to each of the two major experimental conditions--old and new. Likewise, all available rescue crews ran the exercise using both old and new communications equipment. The experiment was also counterbalanced with respect to problems. Easy and hard problems were presented equally in both experimental conditions. It was felt that

all other variables would have random effects on the two systems, so that neither system would have any unfair advantage. As will be seen later, relying on random uncontrolled, variables increases the experimental error considerably so that only very large effects will be detected.

3. Design and Analysis. The original plan called for evaluating the communications equipment as follows:

Barksdale AFB - Large frame aircraft
Nellis AFB - Small frame aircraft, structures
Tyndall AFB - Small frame aircraft, structures

Modifications made to this plan will be described below as each of the studies is covered in depth. When originally conceived, the basic structure of the experiment employed a two-factor completely crossed design. In addition to the main experimental variable (old or new system), differences in shifts were a factor of interest. Also, we wanted to assess time of day and problem differences. This was the design used in the Barksdale study. After it was found that time of day appeared to have no significant effect, further consideration of this factor was dropped. Consequently, in the Nellis study, nearly all exercises were conducted in the daytime. Analysis of variance (ANOVA), t-tests and Chi Square were used, as appropriate, for detecting differences. In the Tyndall study, a single-subject, time series approach was used, and trends are described without statistical analysis.

4. General Procedures. Pilot work, accomplished at Tyndall AFB in February 1978, helped to define the problem, develop an approach, and refine procedures used in the experimental phase. Problems varying in complexity were devised. Appendix A contains a complete description of all problems used in the study. The general procedure was for the shift on duty to respond to an exercise message from the alarm room, proceed as directed to the simulated burning aircraft or structure, simulate actions bringing the fire under control, and begin a rescue attempt. Rescue personnel would then receive situation cards describing a problem, e.g. trapped crew members, for which they had to take appropriate action. Tape recordings were made of these exercises for the purpose of counting the number and quality of communication attempts. Use of a stop watch at well defined start and stop points provided a record of time.

BARKSDALE STUDY

1. Procedures. Sixteen test exercises were accomplished at Barksdale AFB during a 4-day period in March 1978. Half were conducted using the B-52 aircraft, the other half using the KC-135 tanker. Table 1 depicts the design and obtained measures on the criterion variables. Eight problems were administered to each shift. Bomber problems were rewritten to be nearly the same as the tanker equivalent. This was possible by changing the name of the injured crew-member, i.e. from boom operator to navigator. Practice effects were controlled by having a large number of problems and presenting them on different days in counter balanced order (Reference Table 1).

2. **Results**

a. A series of preliminary analyses established that there were no mean differences in rescue time for day versus night or for type aircraft. Contrary to expectation, however, the problems could not be shown to vary in difficulty. These results are presented in Table 2.

b. The main analysis was a 2x2 factorial ANOVA with shift and type system (new or old) as the experimental variables, and rescue time and number of communications as criterion variables. The only significant effect was for shift; that is, Shift A was clearly faster at solving the problems using both the old and the new communications equipment. Averaging over both shifts, use of the new equipment resulted in slightly faster times (Mean_{NEW} = 10 minutes, 29 seconds; Mean_{OLD} = 11 minutes, 40 seconds), but this difference was not statistically significant. Appendix B contains the ANOVA summary table.

c. With respect to number of communications attempted, a similar analysis significantly favored the new communications equipment. Sixty-seven percent more communications were initiated in solving the problems with the new equipment than the old; totals were 459 and 275 respectively. This result held true for both shifts. The ANOVA summary table for this analysis appears in Appendix B.

d. Using Chi Square, a comparison was made between success rates of the old and new communications equipment. As can be seen in Table 3, the percentage of successful communications was quite high and similar in both old and new communications conditions. Differences between conditions were not significant.

4. **Discussion**. The large time difference between shifts cannot be attributed to experience since both rescue crews were similar on this variable; both were quite experienced and well trained. One crew, however, had more aggressive leadership from the Deputy Chief. He stressed speedy execution of the problems more than his counterpart on the other shift. The problems were quite sensitive to this kind of orientation. While there was no time advantage for the new communications system, it did appear to be more than adequate for solution of the problems. In terms of number of communications generated in the exercises, the new system was clearly superior. The increased volume of communication, however, neither hindered nor facilitated task performance.

NELLIS STUDY

1. **Small Frame Aircraft**. Although pilot work at Tyndall with the T-33 had revealed that dealing with fighter-type aircraft can be a simple and fast matter for experienced firefighters, we began at Nellis by implementing our standard approach, i.e., constructing problem situations and timing rescue exercises. After three trials, it became apparent that the problems were too simple to produce the variability needed for a sensitive test of any potential differences between the two types of communications equipment.

Trial 1 was accomplished in an F-15 by the more experienced shift and took only 3 minutes and 20 seconds using the new equipment. Trials 2 (new) and 3 (old) took 7 minutes 10 seconds and 4 minutes 30 seconds respectively. Both used the same problem which dealt with an F-15 aircraft, and were performed by the less experienced shift. It seemed that the observed time difference favoring the old equipment was due more to a practice effect than any inherent difference in communications capability. In the light of procedural complications, the study was refocused to exclude small frame aircraft.

2. Structural exercises. The structures involved in this exercise were a small wood frame building and a large aircraft hangar. Eight exercises were run during 2 days in March, 1978. Once again, problems were devised to represent different levels of complexity. Table 4 shows the design and data on the dependent measures.

a. Results. Due to the fact that there simply were not enough within cell observations for ANOVA, a series of t-tests was run to explore relationships in the data. As can be seen from Table 5, no significant differences were found. With only eight total observations, even the 5 minute 10 second average difference between shifts could have been due to chance. Average number of communication attempts was greater in the exercises involving the new communications equipment (62 versus 51), but not significantly so ($t = -.59$, $df = 5$). Table 6 shows a breakdown of successful and unsuccessful attempts by system. No difference in rates was observed.

b. Discussion. It was clear to experienced observers (and confirmed by time-in-position data on the crews) that one was much less experienced in dealing with the exercise problems. In addition, problem 3, being a composite of the other three problems, was highly complex and should have been statistically slower than the rest. The failure of the statistical analysis to detect these differences was due partly to the small sample size but more importantly due to the large amount of variability in performance. In essence, the Nellis design represented half of the Barksdale design and could have been expanded to match the previous design by collecting more observations. We decided not to continue in this way because of the variability problem and because the same trends were emerging--a difference between shifts but no statistically significant difference between communication systems. A more sensitive test of the hypothesis was sought in the next series of exercises.

TYNDALL STUDY

1. Procedures. In an effort to reduce the variability which had made experimental effects difficult to detect in both previous studies, we changed our evaluation strategy to a single-subject time series procedure. This involved running one complex exercise repeatedly with the same rescue crew. The rationale underlying such an approach is to observe the effect of an innovation after a repeated series of trials done in the conventional way. If the innovation has any effect, it should be evident

through a sharp change in performance. On trials following the innovation, the conventional method is reinstituted and performance should return to its former level. One disadvantage present here was that we could not apply standard sampling statistics because they would require several observations on each trial. However, we chose to use descriptive methods and attempt to reduce the variability by using a single problem and a single crew, with one replication.

2. Results. Results are presented separately for the two crews in Figures 1 and 2 and Table 7. The new equipment was used on trials 1 and 2 in order to provide familiarity with it so that changes in rescue time during subsequent reintroduction could not be attributed to lack of familiarity. Trials 3, 4 and 5 utilized old equipment for the purpose of establishing a baseline and allowing performance to stabilize at a level which would reflect practice effects. Trial 6 introduced the new equipment and was considered to be the critical trial. Return to the old equipment on trials 7 and 8 was made so that we could observe whether rescue times would return to their former level.

Results indicated that (for both teams) use of the new equipment was accompanied by slower rescue times, markedly for team 1 and very slightly for team 2. In both instances times declined upon return to the old methods.

3. Discussion. What appears to be a rather straightforward result in favor of the old equipment is somewhat clouded by another circumstance. It was originally intended that each trial would be held on a different day to minimize fatigue and keep motivation constant. However, scheduling and operational considerations compressed the eight trials into three days. In retrospect, this seems to have been a mistake. Under the conditions as actually run in the test, one can interpret Figures 1 and 2 as showing an effect that may be reflecting merely within-day changes in motivation level or increased task attention, similar to the end spurt of activity one often produces when the goal is in sight. It should be noted that there seems to be a clear tendency for time to decline within a single day, and for the first trial of a following day to be longer than the last trial of the previous day--somewhat like a warm up effect.

One final note on the Tyndall study. Crews at Tyndall, in contrast to most other fire stations, were using the VOICE PACK as the old communications equipment. This device amplifies the voice and makes voice communication possible between team members. It also allows use of the walkie-talkie without pausing to raise the mask and speak into the microphone. Thus, the old equipment had much of the capability of the new equipment. Ordinarily this would not have been the case. Any result favoring the new equipment, although none occurred, would have been an extremely stringent test.

ATTITUDES

1. Procedure. A short 11-item questionnaire was devised to elicit user reaction to the new equipment (See Appendix C). Data was requested

on background position, and perceived efficiency of communications equipment. One open-ended item was included to investigate critical incidents which impacted performance. The questionnaire was filled out after crews had completed all the exercises at each of the bases.

2. Sample Characteristics. In all, 30 usable questionnaires were returned; 8 from Barksdale, 10 from Nellis, and 12 from Tyndall. Twenty two of the 30 responses were from Rescue Team personnel, and five from Deputy Chiefs. Thus, the vast majority of response came from personnel who had direct experience with the new communications equipment. Total firefighting experience of the respondents ranged from less than 1 to 31 years, the median being 8 years. Sixteen of the responses pertained specifically to the structural helmet, six to the crash helmet, and four to the radio which was used by the Deputy Chief. Questions 6 through 11 were coded using Likert Scale values (1-5) where one was unfavorable and five represented an answer most favorable to the new communications equipment. For example, in question 7 the response "All of the messages were clear" received a 5, while in question 8 the response "Never" was scored as 1. The midpoint of the scale was 3, which represented a neutral opinion toward the new equipment.

3. Results. Table 8 gives means and standard deviation for the six opinion items broken down by category of equipment used and for the total sample. It can be seen that the mean values were uniformly favorable toward the new equipment. The distribution of responses was skewed markedly in the favorable direction. The variation in opinion within any one question was generally small, thus indicating a substantial degree of agreement between respondents. No statistically significant differences between the crash and the structural rescue situations were detected. Results for specific critical incidents are not reported here but were incorporated into the observations made by the human factors specialists and are included elsewhere in the report.

4. Discussion. Clearly, the firefighters sampled in this study liked the new equipment, could hear messages clearly and had little difficulty being heard by others. Question 11 was a crucial question in terms of overall favorability and 26 of the 30 responses (or 87 percent) indicated that, compared to conventional procedures, the new equipment improved or greatly improved their effectiveness in dealing with the emergency situations.

SECTION V
COMMUNICATIONS/HELMET EVALUATION

Two different styles of helmets were used; structural and crash. The structural helmet had the off-on-volume control switch, push-to-talk (PTT) switch, and speaker mounted on the ear flap. The microphone was mounted at the end of a semi-rigid wire extending from the ear flap to the center of the front bill. The microphone could be positioned anywhere in front or side of the firefighter's face. The crash helmet had the off-on-volume control switch mounted on the side and the PTT switch mounted in the front. The speaker and microphone were placed inside the helmet in a similar configuration as the structural helmet.

TEST RESULTS

The first system tests were conducted at Tyndall AFB FL. The equipment was operated by two different rescue teams consisting of three men each. Both the structural fire helmet and the crash fire helmet were operated in its respective environment.

The following communication problems occurred during testing of the helmets:

a. The structural helmet communication system cannot be interfaced with the present Air Force inventory air mask. Poor quality audio resulted when speaking through the air mask's voice box into the radio microphone. Direct coupling of the air mask's microphone into the radio did work. However, the voice operated transmitter (VOX) control circuit was activated by the breathing noises inside the mask. In addition the audio cable required from the mask to the helmet can hang on objects and be accidentally disconnected or result in personal injury.

b. Syllables and words were lost at the beginning of transmission when using VOX in both the structural and crash helmets.

c. Wind and breathing noise triggered the VOX in both the structural and crash helmets. With the radio keyed by the VOX the other radios receive constant noise which blocks the transmitters preventing further communications until the VOX is deactivated.

The radios operated well over 2,000 feet and no radio frequency (RF) penetration problems were experienced. Receiver audio level was at a sufficient level for hearing in a high noise area without being objectionable in a quiet area.

The next system tests were conducted at Barksdale AFB, LA. The crash fire helmet was the only system tested. Two different rescue teams consisting of three men each participated in day and night exercises on a KC-135 refueler aircraft and a B-52 bomber aircraft.

Breathing noise and wind activated the VOX. After several attempts a microphone location (about 2 inches from operator's cheek with voice

element facing down) was found that resulted in minimal noise, good voice communication, and acceptable VOX operation. However, the operators were required to speak at an above normal level to maintain these conditions. No interference or loss of communication was experienced in either of the large frame aircraft. It was also noted that the control on the side of the helmet adjusted the received audio level instead of the squelch level as stated in the specifications.

Tests on the structural and crash helmets were conducted at Nellis AFB NV. Two different rescue teams consisting of three men each participated in day and night exercises on fighter aircraft and on metal and frame single story structures.

No new problems were experienced with the crash helmet communication system. However, the fire director had difficulty in hearing the rescue team's transmissions due to the aircraft engine noises on the flight line.

The structural fire helmet communication system performed unsatisfactorily. The face mask microphone is poor quality and resulted in unintelligible transmission about 50 percent of the time. The problem became worse when the breathing apparatus was used as the regulator noise and breathing noise continuously activated the VOX.

No RF penetration problems were experienced inside both a metal structure (hangar) and a single story frame structure. These tests were conducted using the structural helmet without the breathing apparatus specifically for checking RF penetration of the ultra high frequency (UHF).

Additional RF penetration checks were conducted at Tyndall AFB FL. Various structure types were used with no communication problems encountered.

EVALUATION

The structural helmet communication system did not meet the air mask compatibility requirement contained in the specification. Research into similar conditions such as pilot communication and air rescue operations provided no solutions. The VOX operation and breathing apparatus operation (firefighting requires much more physical exertion) are unique requirements. This helmet will meet the receive only requirements.

The crash helmet communication system functioned satisfactorally.. However, some changes are required to improve VOX operation, general radio operation, and voice quality. Since the VOX circuitry can not distinguish between voice and breathing noise, noises inside the helmet must be sufficiently reduced.

The battery charger supplied requires additional circuitry to provide full charge indication, failure indication, and circuit protection for each radio.

SECTION
CONCLUSIONS

One main objective of the firefighting communications systems test was satisfied by this, and a previous evaluation (DOD-AGFSRS-76-S). Individual firefighter communications will improve fire fighting performance by virtue of improved command and control. The following conclusions were drawn from this evaluation.

1. It is possible to combine crash helmet head protection, breathing air and a communications system into a single unit, which can successfully be utilized by USAF firefighters.

2. The voice actuated microphones (VOX) as tested are unsatisfactory. Deletion of the voice actuated microphone (VOX) should be considered in favor of a push-to-talk (PTT) controlled microphone.

3. As detected in the evaluation, the need for communications is more essential in large frame aircraft rescue and fire situations.

4. The structural helmet communications system as tested cannot be interfaced with the present Air Force air mask. Deletion of the transmit capability, and retention of the receive capability would be feasible.

TABLE 1. DESIGN AND OBSERVED DATA FROM THE BARKSDALE STUDY

EXERCISE	PROBLEM	ACFT TYPE	TIME OF DAY	SHIFT	COMM SYSTEM	RESCUE TIME	NO. COMM ATTEMPTS	PERCENT SUCCESS
1	1	T[a]	D[b]	1	O[c]	6:35	21	90
2	2	T	D	1	N	8:55	57	100
3	3	T	N	1	O	9:05	34	88
4	4	T	N	1	N	9:35	80	96
5	4	T	D	2	O	16:15	34	97
6	3	T	D	2	N	13:52	45	100
7	2	T	N	2	O	18:40	30	100
8	1	T	N	2	N	12:10	56	100
9	7	B	D	1	N	8.07	49	98
10	8	B	D	1	O	8:20	39	97
11	5	B	N	1	N	8:48	58	91
12	6	B	N	1	O	10:09	49	98
13	6	B	D	2	N	13:13	79	99
14	5	B	D	2	O	12:05	37	100
15	8	B	N	2	N	9:10	45	100
16	7	B	N	2	O	12:10	40	100

a. T = Tanker; B = Bomber   b. D = Day; N = Night   c. O = Old; N = New

TABLE 2. PRELIMINARY ANALYSIS OF RESCUE TIMES AT BARKSDALE

		MEAN		SD		n	t	F	p
		(Ft)	(In)	(Ft)	(In)				
DAY		10	55	3	24	8			
NIGHT		11	13	3	17	8	0.18		0.859
TANKER		11	53	4	7	8			
BOMBER		10	15	1	58	8	1.01		0.336
PROBLEM	1	9	22	3	56	2			
	2	13	47	6	53	2			
	3	11	28	3	22	2			
	4	12	55	4	42	2			
	5	10	26	2	19	2			
	6	11	41	2	10	2			
	7	10	8	2	51	2			
	8	8	45		35	2		0.413	0.869

TABLE 3. QUALITY OF COMMUNICATIONS ATTEMPTS AT BARKSDALE

	Successful	Unsuccessful	Percent Success
Old	275	9	97
New	459	10	98

$X^2 = 0.41$ $p = 0.52$

TABLE 4. DESIGN AND OBSERVED DATA FROM THE NELLIS STUDY

EXERCISE	PROBLEM	STRUCTURE	SHIFT	COMM SYSTEM	RESCUE TIME	NO COMM ATTEMPTS	PERCENT SUCCESS
1	1	B[a]	1	N[b]	2:55	27	84
2	2	B	1	O	7:30	62	82
3	3	H	2	N	16:30	70	86
4	3	H	1	O	12:10	59	91
5	4	H	1	N	4:10	57	97
6	1	B	2	O	9:00	-[c]	-
7	2	B	2	N	13:10	95	93
8	4	H	2	O	8:45	32	91

a. B = Frame building: H = Hangar

b. N = New System: O = Old System

c. Missing due to tape malfunction

TABLE 5. ANALYSIS OF RESCUE TIMES AT NELLIS

	MEAN	SD	n	t	F	p
Shift A	6:41	4:08	4			
B	11:51	3:42	4	-1.86		0.11
OLD	9:21	1:59	4			
NEW	9:11	6:41	4	0.05	0.96	
BUILDING	8:09	4:14	4			
HANGAR	10:24	5:14	4	0.67		0.53
PROBLEM 1	5:58	4:18	2			
2	10:20	4:00	2			
3	14:20	3:04	2			
4	6:27	3:14	2		2.23	0.23

TABLE 6. QUALITY OF COMMUNICATION ATTEMPTS AT NELLIS

	SUCCESS	UNSUCC	PERCENT SUCCESS
OLD	154 (3 exer)	23	87
NEW	249 (4 exer)	25	91

$X^2 = 1.31$ $p = 0.25$

TABLE 7. RESCUE TIMES--TYNDALL EXERCISES

DAY	1			2			3	
SYSTEM	N	N	O	O	O	N	O	O
SHIFT 1	9:31	-	6:40	6:05	5:10	8:45	5:50	5:40
SHIFT 2	6:30	4:15	6:50	5:00	5:15	5:50	4:40	4:30

TABLE 8. ITEM RESPONSES ON OPINION QUESTIONNAIRE

	CRASH		STRUCTURAL		ALL	
Item	Mean	SD	Mean	SD	Mean	SD
6	3.8	0.4	3.8	0.8	3.9	0.8
7	3.8	0.4	3.6	0.6	3.5	0.6
8	4.2	0.4	3.4	0.8	3.8	0.8
9	4.5	0.5	3.9	0.7	4.1	0.7
10	4.0	0.6	3.7	0.7	3.9	0.7
11	4.5	0.8	4.1	0.9	4.3	0.8

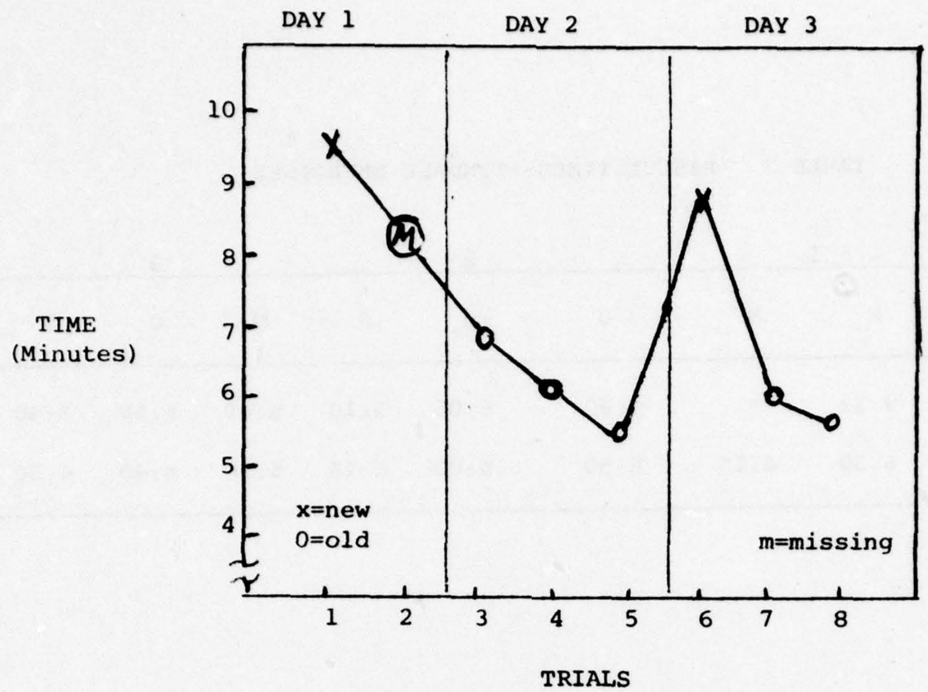

Figure 1. Tyndall Rescue Time: Team 1

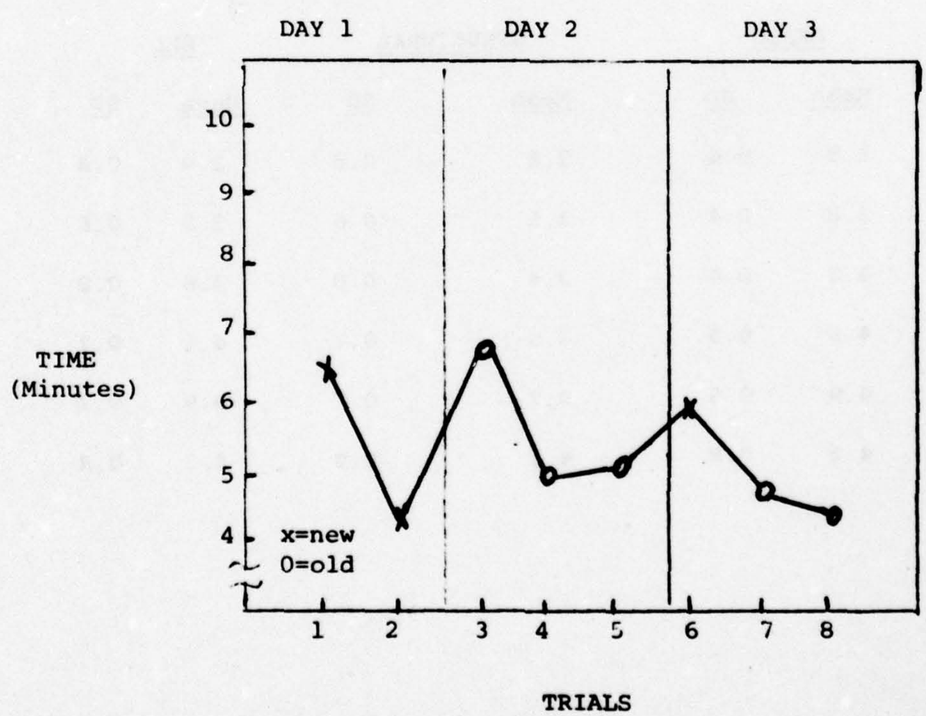

Figure 2. Tyndall Rescue Time: Team 2

xx

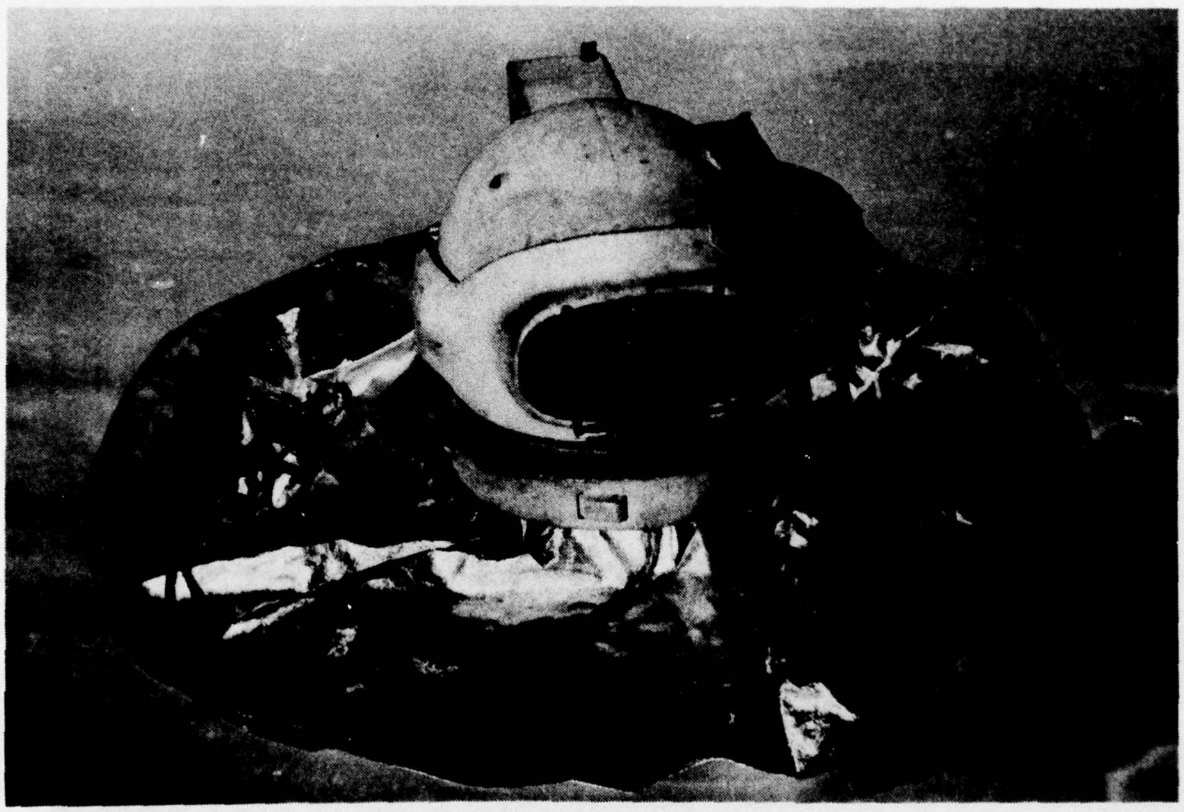

Figure 3. Aircraft Fire Fighting Helmet

xx

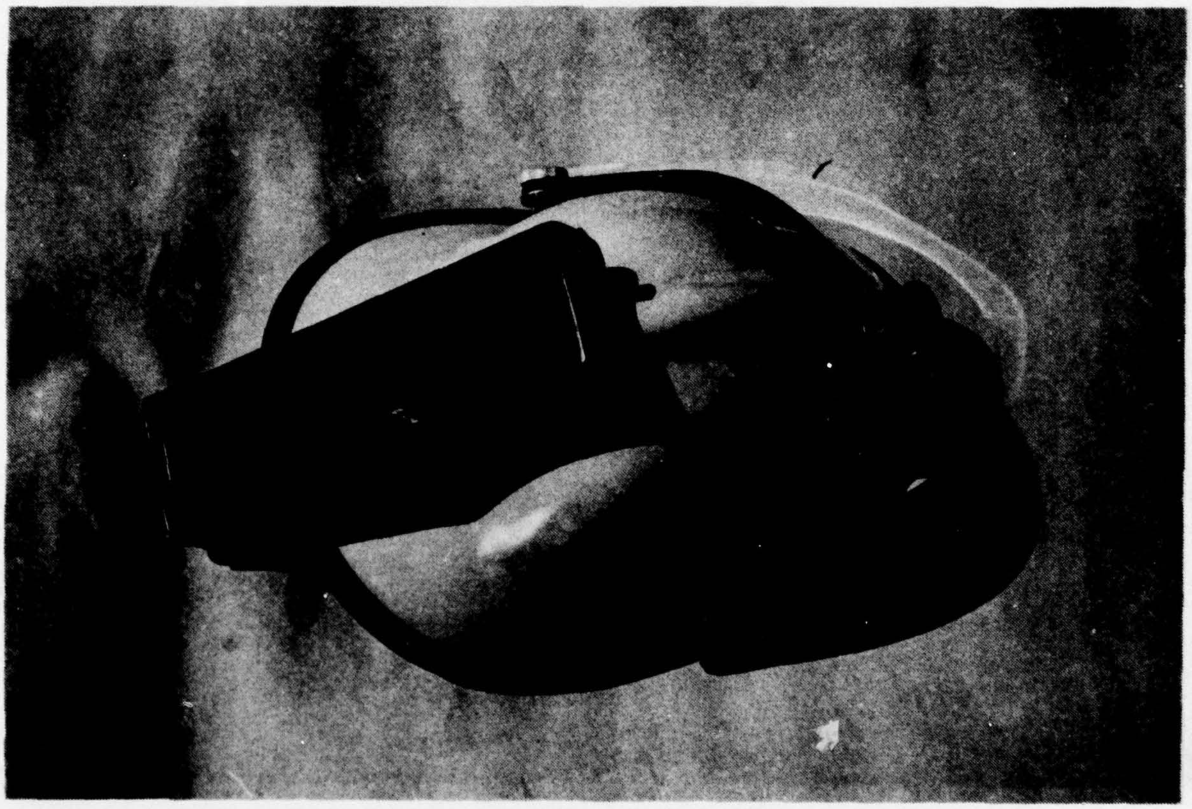

Figure 4. Structural Fire Fighting Helmet

APPENDIX A

PROBLEM SITUATIONS

BARKSDALE PROBLEMS

1. While entering normal crew door, there was an explosion, the handlineman was injured.

2. The forward control console is jammed across pilots' right front, requires Hurst tool.

3. The co-pilot has a compound fracture and bone protruding out from elbow and bleeding.

4. Boom operator is injured, suspect a broken back.

5. While entering normal crew door, there was an explosion, the #2 rescueman was injured.

6. Navigator is injured, suspect a broken back.

NELLIS PROBLEMS

1. Victim with a broken leg, bone protruding from wound and bleeding; take necessary action.

2. Trapped casualty under a fallen truss; require the K-2 saw, fireman's axe, and first aid equipment.

3. Victim with a broken leg, bone protruding from wound and bleeding; take necessary action. Trapped casualty under a fallen truss; require the K-2 saw, fireman's axe, and first aid equipment. We have located a victim who has been overcome by smoke and possible broken back; take necessary action.

4. We have located a victim who has been overcome by smoke and possible broken back; take necessary action.

TYNDALL PROBLEM

This problem consisted of three situations:

1. While attempting to secure the utilities, rescueman #3 discovers a gas leak.

2. A victim is trapped, requiring the Hurst tool.

3. Roof collapses on one of the rescuemen.

APPENDIX B

ANALYSIS OF VARIANCE SUMMARY TABLES

TABLE B-1. ANALYSIS OF VARIANCE: RESCUE TIME

SOURCE OF VARIATION	SS	df	MS	F	p
Shift	325185.063	1	325185.063	20.771	0.001
Sys	20235.063	1	20235.063	1.292	0.278
Shift x Sys	32490.063	1	32490.063	2.075	0.175
Residual	187869.250	12	15655.771		
Total	565779.437	15	37718.629		

16 Cases were processed.
0 Cases (0 PCT) were missing.

TABLE B-2. ANALYSIS OF VARIANCE: NUMBER OF COMMUNICATIONS

SOURCE OF VARIATION	SS	df	MS	F	p
Shift	27.563	1	27.563	0.188	0.673
Sys	2139.063	1	2139.063	14.566	0.002
Shift x Sys	18.063	1	18.063	0.123	0.732
Residual	1762.250	12	146.854		
Total	3946.938	15	263.129		

16 Cases were processed.
0 Cases (0 PCT) were missing.

APPENDIX C

OPINION QUESTIONNAIRE

FIREFIGHTER/CRASH RECUE COMMUNICATIONS
QUESTIONNAIRE/LOG

YOUR NAME:______________________________Date:____________

TIME OF OPERATION__________________AFSC__________LOCATION__________
(24 Hour Clock)

CIRCLE THE ANSWER WHICH BEST APPLIES

1. What is your position (or duty title)?
   a. Handlineman/Nozzleman
   b. Driver/Hydrantman
   c. Rescue Team Member
   d. Assistant Chief
   e. Deputy Chief
   f. Chief
   g. Other_____________________________________
   (Describe)

2. How many years experience do you have in fire fighting/crash rescue?_______________

3. *How many* years in your present position?_______________

4. What piece(s) of the equipment being tested did you utilize during this exercise? ____________________

5. What type of head gear was worn while testing equipment?

   a. Crash hood
   b. Crash hood with breathing apparatus
   c. Structural helmet
   d. Structural helmet with breathing apparatus
   e. Other _____________________________________
   (Describe)

6. When inactive or in non-emergency situations, how well could you hear transmitted messages with the radio gear you used?

   a. All of the messages were clear.
   b. Most of messages were clear.
   c. Some parts could be understood, some could not.
   d. Most of the messages were clear

7. When fighting a fire, or during an emergency, how well could you hear transmitted messages?

   a. All of the messages were clear.
   b. Most of messages were clear.
   c. Some parts could be understood, some could not.
   d. Most of the messages were clear.
   e. All of the messages were clear.

8. When transmitting a message, was it received by the intended communicator?

   a. Always
   b. Most of the time
   c. Often
   d. Seldom
   e. Never

9. How often could you determine who had transmitted a message to you?

   a. Always
   b. Most of the time
   c. Often
   d. Seldom
   e. Never

10. When fighting a fire, or during an emergency, how often were attempts to transmit a message to another fire fighter, or other receiver, blocked?

   a. Always
   b. Most of the time
   c. Often
   d. Seldom
   e. Never

   Comment:____

11. What is the effect on your fire fighting or emergency response task of having radio communications with the other firefighting/crash personnel at the scene?

   a. Greatly improves my response
   b. Improves my response
   c. Has no direct effect
   d. Interferes with my response
   e. Greatly interferes with my response

   Comment:____

12. Describe a specific incident that had a significant impact on your performance or safety during this exercise. Whey did it happen? Can it be avoided? How?

Comment:____

USE OTHER SIDE FOR ADDITIONAL COMMENTS:

INITIAL DISTRIBUTION

DDC/DDA	2
HQ AFESC/RD	2
HQ AUL/LSE 71-249	1
USA Facilities & Engineering Support Agency	1
USA/TRADOC	1
Navy Department	1
HQ NAVFAC/IOF	1
Naval Research Laboratory	5
NASC	1
FAA/NAFEC	2
NGB/DEM	1
AFRES/DEMF	1
HQ PACAF/DEMF	1
HQ TAC/DEMF	1
HQ USAFE/DEMF	1
Ansul Company	1
NAVSEA/0351	1
NAVSEA/CC	1
HQ MAC/DEMF	1
HQ AAC/DEMF	1
HQ AFSC/DEMF	1
HQ SAC/DEMF	1
HQ ATC/DEMF	1
HQ ADCOM/DEMF	1
HQ AFLC/DEMF	1
WRALC/MMIRAB	1
HQ AFESC/DEF	5
HQ AFESC/RDCF	10
3340 TTO/TTMF	2
National Fire Prevention & Control Administration	1
HQ AFSC/SDAE	1
FAA/AAP-720	1
National Bureau of Standards	1
Naval Air Technical Training Ctr	1
Pemco Products	1
Naval Ship Engineering Ctr	2
62 ABG	1